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OBJECTIVE EVALUATION OF THE MATURITY FACTOR IN PROCESSED SWEET CORN

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The United States Standards for Grades of Canned Whole Kernel Corn (8) 1/ and for Frozen Whole Kernel Corn (9) recognize that tenderness-maturity is the outstanding factor of quality. In these two standards 40 and 50 points respectively are assigned to this quality factor. Considering the fact that other factors of quality, such as flavor and color, are also associated with maturity it may be stated that the grade for processed whole kernel sweet corn rests largely on the evaluation of the tenderness-maturity factor.

It is, therefore, desirable for the buyer as well as the processor and inspector of sweet corn that a reliable objective method be available for the evaluation of tenderness-maturity. Although the grade is evaluated by subjective methods, a more accurate evaluation may be accomplished by suitable objective methods. In seeking a suitable objective method this cooperative work was undertaken.

The work on processed sweet corn has been applied primarily to the canned product (7), relatively little study being made of frozen sweet corn (2). Of the many methods proposed for the processed product, the measurement of solids insoluble in alcohol (A.I.S.) appeared to be the most satisfactory. However, even this method did not appear to be sufficiently accurate under all conditions of varietal, climatic, and geographic variations to justify its use in place of subjective evaluations with respect to qualities of canned whole kernel corn above U. S. Grade C quality. Previous work at the University of Maryland (4) on the development of objective methods for measuring raw corn for processing indicated that moisture, pericarp, and kernel size of the corn are important factors that greatly influence the tenderness and maturity of sweet corn. For these reasons a trimetric test based on these three factors was undertaken on canned and frozen whole kernel corn. As the moisture content of processed sweet corn might be influenced by variations in processing procedures, the moisture part of the trimetirc test was replaced with the determination of alcohol-insoluble solids, which is closely related to total solids, and which has been shown to be in itself one of the best measures of quality of processed sweet corn.

1/ The underscored numbers in parentheses refer to Literature Cited, p. 9

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Materials and Methods

During the 1953 growing season, ten varieties of sweet corn, considered to be the most suitable for processing, were grown at the Salisbury farm of the Maryland Agricultural Experiment Station. On the basis of careful pre-testing with the trimetric method, each of these varieties was harvested four times, at four stages of maturity, in order to provide samples that were expected to grade high fancy, low fancy, extra standard, and standard quality after processing (table 1). Immediately following each harvest for each variety, each lot was husked, trimmed, and cut, the kernels again were tested by the trimetric method, and the remaining material was processed as canned and frozen whole kernel corn in accordance with common commercial practice, at the nearby plant of John H. Dulany and Son. In this way 40 experimental samples each of canned and frozen sweet corn of known history were prepared.

In addition, 53 canned and 32 frozen samples of commercially packed sweet corn were collected by members of the Agricultural Marketing Service from processors in Maryland, Maine, Pennsylvania, Illinois, Indiana, Michigan, Wisconsin, Iowa, Minnesota, Colorado, Utah, Idaho, and Washington.

All of the 93 samples of canned and 72 samples of frozen corn were brought to the laboratories of the Fruit and Vegetable Division, Agricultural Marketing Service, Washington, D. C., where the following analyses were made:

(1) Subjective tenderness-maturity scores by three members of the Agricultural Marketing Service, in accordance with the official procedures (8, 9).

(2) Panel scores as provided by a group of 6 judges (for the frozen samples) and 10 judges (for the canned samples), drawn from among sweet corn packers, U. S. Department of Agriculture personnel, and University of Maryland personnel. Each judge was required to score the maturity of each sample subjectively on a 10 point scale, where a score of 10 was equivalent to top fancy maturity, and a score of 1 was substandard.

(3) Objective determinations: The percentage of alcohol-insoluble solids (A.I.S.) was determined in accordance with the Food and Drug method (1), and pericarp and kernel size as described by Kramer et al. (6).

The data were analyzed statistically, to determine the correlations between the various tests, and nomographs were then constructed from the multiple regression equations by which the grade scores for maturity could be determined from objective test data.

Discussion of Results

Correlation Analyses

The critical test for the suitability of any objective test is its degree of agreement with human evaluation, as obtained by the use of sensory testing panels (5). The degree of agreement may ordinarily be evaluated statistically by the use of the coefficients of correlation and determination. These coefficients between panel scores and the various grading methods are presented in table 2.

The coefficients of correlation between average panel scores and average USDA scores of 0.929 and 0.926, respectively, for the canned and frozen samples indicate an excellent degree of agreement between these two essentially subjective evaluations. This may be taken to mean that the group of three official inspectors evaluated these samples in essentially the same manner as did the larger panel.

The coefficients of correlation between average panel scores and average trimetric values were 0.968 for the canned samples and 0.910 for the frozen samples. As agreement was not perfect, the result indicates that the correlation between the objective and panel scores might have been even higher, had it not been for the error inherent in the panel scores themselves or for factors not measured by the trimetric tests. In order to indicate the percentage of the variability that is explainable on the basis of differences in test results, the coefficients of determination were obtained as shown in table 2.

In the case of the canned samples, the tests explained approximately 94 percent of the variability in tenderness-maturity. For frozen corn the results were similar to those for the canned product, but the accuracy of the tests on the frozen product was somewhat lower. The trimetric test explained about 83 percent of the variability in tenderness-maturity, whereas about 17 percent of the variability appears to be due to error in the panel or objective methods or to factors not measured by the trimetric test. This may be attributed at least in part to the greater error in the determination of percentage A.I.S. in the frozen samples caused by variations in blanching and washing, as corn kernels do soak up water during these operations, and reduce the insoluble solids percentage accordingly. Canned whole kernel corn, on the other hand, being processed in liquid, is always tested under conditions of maximum water imbibition.

In another study on sweet corn quality reported elsewhere (4), it was found that the factor of sweetness added precision to the objective evaluation of frozen whole kernel sweet corn. Sweetness was unimportant for canned whole kernel sweet corn, as sugar is added to this product in the canning operation. It is, therefore, possible that the addition of sugar determination to the other tests included in the trimetric test would result in a somewhat more accurate combined test. The practical advantage of such a more elaborate test, however, is questionable.

It may be noted from table 2 that correlations between panel scores and alcohol-insoluble solids are lower than those between panel scores and all three trimetric tests, even for these data on 10 varieties of yellow corn which do not differ widely in their quality characteristics. Had other varieties been included, or other growing conditions, the advantages of the trimetric test over any single test would have been even more apparent.

Nomographs for Calculating Scores

To receive a score in the Grade A classification the United States standards for processed corn require that the corn be tender. "Tender" means that the kernels are in the milk or early cream stage and have a tender texture. Kernels in the pre-milk or "blister" stage of development, which are easily detected visually, have not reached the most desirable stage of maturity and are not satisfactory for canning or freezing. When dealing with samples of sweet corn of this stage of maturity neither the trimetric test nor the nomographs for assigning the tenderness-maturity score gives satisfactory results and is, therefore, not applicable to sweet corn in this stage of maturity.

The nomographs developed from the relationship between the objective test data and panel scores are presented in figures 1 and 2. The nomograph presented in figure 1 may be used to determine the tenderness-maturity score of canned whole kernel sweet corn from tests of percentage of alcohol-insoluble solids, pericarp, and kernel size of the canned corn. The nomograph presented in figure 2 may be used to determine the tenderness-maturity score of frozen whole kernel sweet corn from the same three tests on the frozen material.

The USDA scores, as well as the actual and predicted trimetric results for the 80 experimental samples, are presented in table 1. The USDA scores and actual trimetric results were obtained by tests of the processed product, whereas the predicted scores were calculated from tests on raw corn conducted by the University of Maryland using the proper nomographs. It may be noted that there is excellent agreement between the USDA scores and those calculated from trimetric data as obtained from the processed samples, and as predicted from data obtained on the original raw corn.

Results with Commercial Samples

As stated above, this work was undertaken because an objective method for determining the tenderness-maturity of canned and frozen whole kernel sweet corn is needed. A comparison of USDA tenderness-maturity scores obtained on the commercial samples with scores by the trimetric method is presented in table 3 for 53 samples of canned and 32 samples of frozen corn. These samples were selected because they were of maturity near the dividing line between fancy and extra standard for the tenderness and maturity factor. When compared with the trimetric scores, the scores by the USDA inspectors were more lenient, on the average.

Summary and Conclusions

This paper presents the results of a study to find a reliable objective test to determine the tenderness-maturity of processed whole kernel corn. The data show a good correlation between the results of the trimetric test, which is wholly objective, and the results of subjective panel evaluation of the tenderness-maturity factor. On the basis of examination of numerous samples, it has been shown that the trimetric test, consisting of percentage of alcohol-insoluble solids, tenderness of pericarp, and kernel size may be used with considerable reliability to evaluate the tenderness-maturity of canned or frozen whole kernel corn. In the case of sweet corn in the pre-milk or blister stage of maturity the trimetric method does not give satisfactory results and is, therefore, not applicable.

This objective procedure, although somewhat less accurate for frozen than for canned corn, may be used to some extent as a guide for in-plant quality control as well as for verification of organoleptic determination of tenderness-maturity. The extent of its practical application may be somewhat limited by the time required to complete the test.

TABLE 1. Comparison of actual and predicted tenderness-maturity evaluation scores of experimental samples of canned and frozen whole kernel sweet corn harvested in August by method of scoring and by variety 1/

Variety	Score of samples: Canned: USDA	Canned: Trimetric: Actual	Canned: Trimetric: Predicted	Frozen: USDA	Frozen: Trimetric: Actual	Frozen: Trimetric: Predicted	Harvested 2/ on August
Golden	37-F	38-F	38-F	46-F	47-F	48-F	11
Crown	35-x	35-x	35-x			46-F	12
Crown	32-x	32-x	32-x	41-x	44-x	43-x	17
Crown	30-s	32-x	30-s	36-s	41-x	38-s	20
Seneca	37-F	39-F	38-F	47-F	49-F	48-F	10
Chief	37-F	37-F	36-F			47-F	11
Chief	36-F	36-F	34-x			45-x	14
Chief	34-x	33-x	32-x	42-x	44-x	42-x	18
G x B	39-F	40-F	39-F	49-F	49-F	49-F	7
G x B	37-F	39-F	37-F			48-F	10
G x B	33-x	33-x	33-x	48-F	44-x	44-x	14
G x B	30-s	31-s	31-s	37-s	41-x	41-x	18
Victory	38-F	40-F	40-F	49-F	50-F	50-F	10
Golden	37-F	37-F	36-F	49-F	48-F	47-F	13
Golden	35-x	34-x	34-x	46-F	45-F	45-F	17
Golden	32-x	33-x	32-x	45-x	44-x	42-x	20
Hoosier	39-F	40-F	40-F			50-F	6
Gold	39-F	39-F	38-F	48-F	48-F-	48-F	7
Gold	35-x	36-F	34-x	45-F	45-F	45-F	10
Gold	33-x	33-x	32-x	45-F	43-x	41-x	14
Sweetan	39-F	40-F	40-F	49-F	49-F	50-F	11
Gold	38-F	36-F	36-F	48-F	48-F	47-F	13
Gold	33-x	33-x	33-x	44-x	43-x	44-x	17
Gold	31-s	31-s	31-s	40-s	41-x	41-x	20
Tendermost	38-F	40-F	39-F	49-F	48-F	49-F	11
Tendermost	38-F	38-F	36-F			47-F	12
Tendermost	36-F	34-x	33-x	44-x	43-x	45-x	17
Tendermost	35-x	34-x	32-x	43-x	43-x	42-x	20
Iochief	38-F	39-F	39-F	49-F	47-F	49-F	10
Iochief	37-F	35-x	36-F	46-F	44-x	47-F	12
Iochief	35-x	33-x	33-x	43-x	45-x	44-x	17
Iochief	30-s	32-x	31-s	40-s	43-x	40-s	20
Double	39-F	39-F	38-F	48-F	49-F	48-F	12
Duty	38-F	36-F	36-F	48-F	46-F	47-F	13
Duty	35-x	34-x	34-x	45-F	44-x	45-F	17
Duty	32-x	32-x	30-s	42-x	41-x	38-s	20
Prosperity	39-F	40-F	39-F	48-F	48-F	49-F	11
Prosperity	38-F	38-F	36-F	48-F	47-F	47-F	13
Prosperity	35-x	34-x	34-x	45-F	42-x	45-F	17
Prosperity	32-x	32-x	31-x	42-x	42-x	41-x	20

1/F U. S. Grade A or U. S. Fancy.
x U. S. Grade B or U. S. Extra Standard.
s U. S. Grade C or U. S. Standard.

2/ Planted June 1, 1953.

TABLE 2. Coefficients of correlation and determination resulting from averages of panel scores and averages of various methods of evaluating tenderness-maturity of experimental samples of canned and frozen whole kernel corn

Method of Scoring	Coefficients of -- Correlation: Canned (r)	Correlation: Frozen (r)	Determination 1/: Canned	Determination 1/: Frozen
			Percent	
USDA	0.929	0.926	86.3	85.7
Trimetric				
Raw	0.928	0.900	86.1	81.0
Canned	0.968		93.7	
Frozen		0.910		82.8
A. I. S.				
Canned	0.916		83.9	
Frozen		0.878		77.0

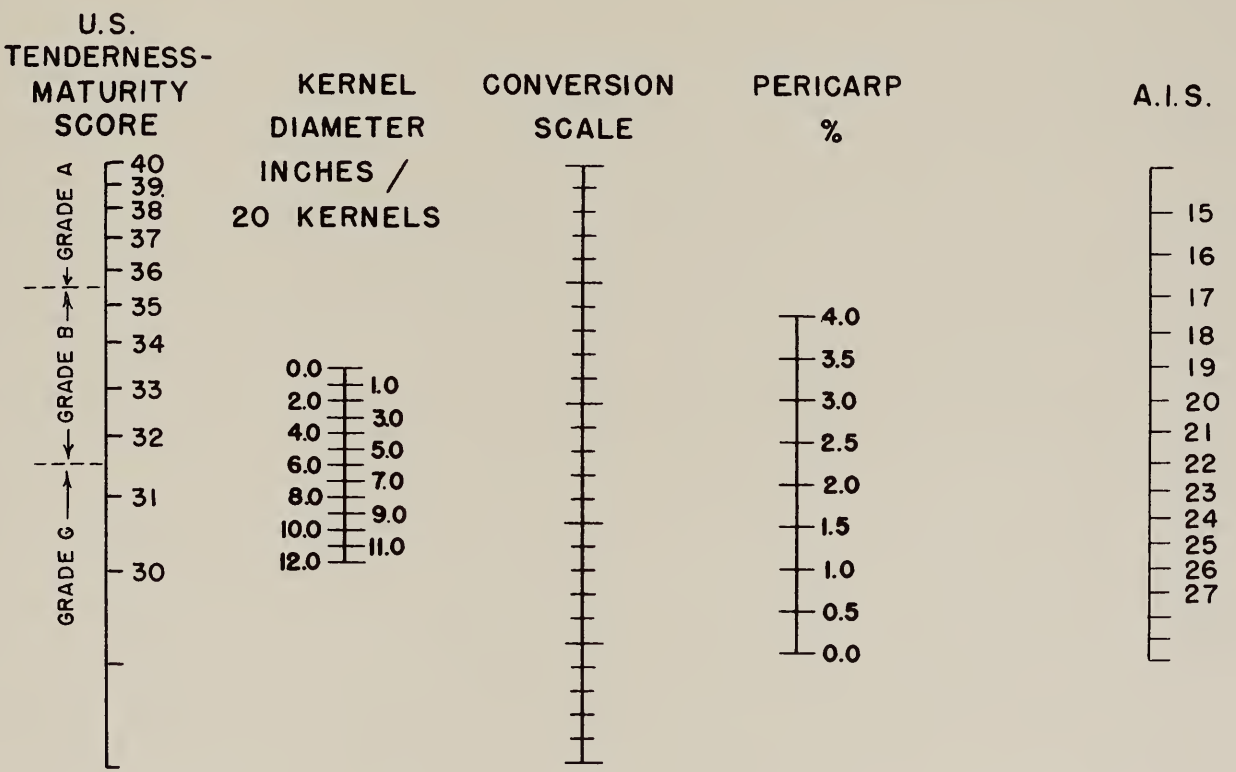
1/ Obtained by multiplying r^2 by 100.

TABLE 3. Percentage agreement between panel scores, USDA scores, and trimetric values on evaluation of tenderness-maturity of commercial samples of canned and frozen whole kernel sweet corn

	Percentage of scores			
	USDA		Trimetric	
	Canned	Frozen	Canned	Frozen
	Percent	Percent	Percent	Percent
Agrees with panel score	68	75	70	72
Lower than panel score	11	9	15	15
Higher than panel score	21	16	15	13

NOMOGRAPH FOR DETERMINING U. S. GRADE FOR TENDERNESS-MATURITY OF CANNED SWEET CORN

From Determinations of A. I. S., Pericarp, and Kernel Size



FROM SELECTED POINTS ON A.I.S. AND PERICARP SCALES, EXTEND LINE UNTIL IT INTERSECTS CONVERSION SCALE. FROM THIS INTERSECTION POINT EXTEND LINE THROUGH SELECTED POINT ON KERNEL DIAMETER SCALE TO TENDERNESS-MATURITY SCORE SCALE. THIS POINT IS THE NUMERICAL TENDERNESS-MATURITY SCORE.

SOURCE OF DATA: SEE LITERATURE CITED, ITEM 4.

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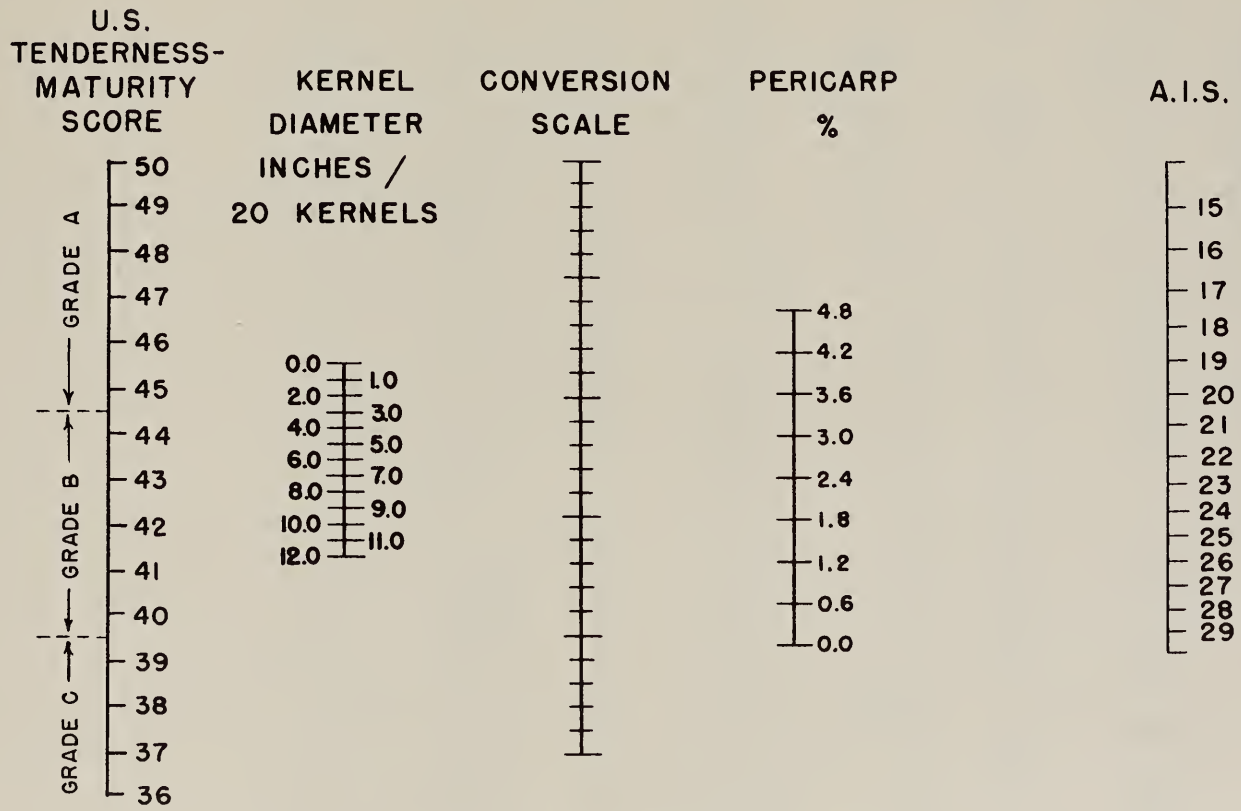
Fig. 1

NOMOGRAPH FOR DETERMINING U. S. GRADE FOR TENDERNESS-MATURITY OF FROZEN SWEET CORN

From Determinations of A. I. S., Pericarp, and Kernel Size



FROM SELECTED POINTS ON A.I.S. AND PERICARP SCALES, EXTEND LINE UNTIL IT INTERSECTS CONVERSION SCALE. FROM THIS INTERSECTION POINT EXTEND LINE THROUGH SELECTED POINT ON KERNEL DIAMETER SCALE TO TENDERNESS-MATURITY SCORE SCALE. THIS POINT IS THE NUMERICAL TENDERNESS-MATURITY SCORE.

SOURCE OF DATA: SEE LITERATURE CITED, ITEM 4.

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Fig. 2

Literature Cited

(1) Title 21 Code of Federal Regulations, Section 51.21 paragraph (b) August 4, 1951.

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(5) _____ An objective approach to the problem of developing grades and standards of quality. Food Drug Cosmetic Law Jour. 7: 23-30. 1952.

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(7) Modern Labels for Canned Foods. National Canners' Association. Washington, D. C., 315 pp. 1951.

(8) U. S. Department of Agriculture. United States Standards for Grades of Canned Whole Kernel (or Whole Grain) Corn. (7 CFR, Sec. 52.269) Effective July 30, 1952.

(9) U. S. Department of Agriculture. United States Standards for Grades of Frozen Whole Kernel (or Whole Grain) Corn. (7 CFR, Sec. 52.271) Effective August 1, 1952.